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BULLETIN IC 67

Analyses and Potential Uses of Selected Shales and Clays, Greene County, Pennsylvania

by John B. Roen

John W. Hosterman

United States Geological Survey

PENNSYLVANIA GEOLOGICAL SURVEY

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PREFACE

Clays and shales constitute a basic mineral resource which may be utilized in the manufacture of various products, depending upon the physical and chemical properties of the raw material. As relatively unglamorous industrial minerals, the economic potential of clay-shale resources is too often overlooked.

This report represents an evaluation of the properties and uses of some of the major clay and shale resources of Greene County. This should be of interest not only to producers and consumers of these mineral commodities, but also to property owners, planners, and officials who are interested in the economic development and growth of Greene County, Pennsylvania.

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Analyses and Potential Uses of Selected Shales and Clays, Greene County, Pennsylvania *

by
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ABSTRACT

Seven clay and shale samples from the Pittsburgh, Waynesburg, Washington, and Greene Formations of Pennsylvanian and Permian age from Greene County, Pa., were analyzed to determine their potential commercial use. Chemical, semiquantitative spectrographic, and X-ray analyses were performed. The chemical and mineral compositions of these clays and shales indicate that they cannot be used in the filler or in the high-grade refractory industries. Slow-fire tests were conducted on all seven samples, and all but one were judged suitable for the manufacture of common, face, and decorative brick. Four samples had expansion characteristics after slow-fire tests and were then quick fired to determine their bloating properties. Three of the four quick-fired samples were fired in the laboratory rotary kiln. One was found to be marginal and one was suitable for the production of lightweight aggregate.

INTRODUCTION

Clay and shale for miscellaneous uses in Pennsylvania and throughout the United States has generally increased, with minor fluctuations, during the past two decades. The net effect, however, is that the production of miscellaneous clay and shale products has increased at about the same rate as the economy of the country. Miscellaneous clays and shales are used chiefly in making fired-clay products, but some clay and shale are used in the unfired form. The unfired uses are as follows: filler in paint, asphalt, and rubber; abrasives, termed "rottenstone"; "clay dummies" to pack dynamite in blasting holes; means of plugging oil and gas wells; and insecticide carrier. These products are easily processed, requiring only drying, grinding, and bagging. Fired products made from miscellaneous clay and shale include common, face, and decorative brick; vitrified sewer pipe, drain, flue, floor, wall, and roofing tile; conduit; pottery; and stoneware. In addition, these clays and shales are used in the manufacture of portland cement and lightweight aggregate. The

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* Publication authorized by the Director, U.S. Geological Survey

greatest demand for miscellaneous clay and shale products will probably be from areas of growing urban population, such as Pittsburgh (Hosterman and others, 1968, p. 175). Also, the rather new use of lightweight aggregate as a skid-resistant constituent in the seal coat of highway surfaces may open a new market for clay and shale. The Commonwealth of Pennsylvania is currently appraising highway construction aggregate for skid-resistant characteristics in a highway surface (Jack Reinhart, oral communication, 1968).

The purpose of the present investigation was to collect and analyze a representative suite of seven clay and shale samples from Greene County, Pa. (Figure 1), for possible use as raw material for ceramic or nonceramic miscellaneous clay and shale products. This report is a preliminary appraisal and not a complete evaluation of the clay and shale resources of the county. It does, however, provide a partial inventory of a potential raw material for industrial use.

Henry Leighton (1932) studied the clay and shale resources of southwestern Pennsylvania. He reported the chemical analyses and firing tests of eight samples from Greene County, two of which are from the Carmichaels Formation, an alluvial deposit of Pleistocene age. Recently, Schroyer (1964) and Grisafe and others (1965) analyzed and evaluated samples of the Carmichaels. The results are listed in the report of project 930 of the Area Redevelopment Administration submitted to the Greene County Planning Commission through Greene County Industrial Development, Inc.

At the time of this writing, the Pennsylvania Geological Survey was studying the clay and shale resources on a state-wide basis. The properties and potential uses of 151 samples are published in the Pennsylvania Geological Survey Bulletin M 51 (O'Neill and others, 1965) as part of the state-wide study.

GEOLOGIC SETTING

Greene County is underlain by coal-bearing strata of the Monongahela and Dunkard Groups of Pennsylvanian and Permian age, except for a small area along the Monongahela River in the southeast part of the county, which is underlain by the Conemaugh Group.

The stratigraphic sequence is made up of cyclic deposits of coal, shale and clay, sandstone, siltstone, and argillaceous limestone (Figure 2). The clastic rocks were deposited on fluvial plains, the limestone in lakes or marshes, and the coals in swamps. The persistent widespread coal deposits are particularly important because they are used as the basic framework for stratigraphic subdivisions and nomenclature. Most of the exposed formations, such as the Pittsburgh, Uniontown, Waynesburg,

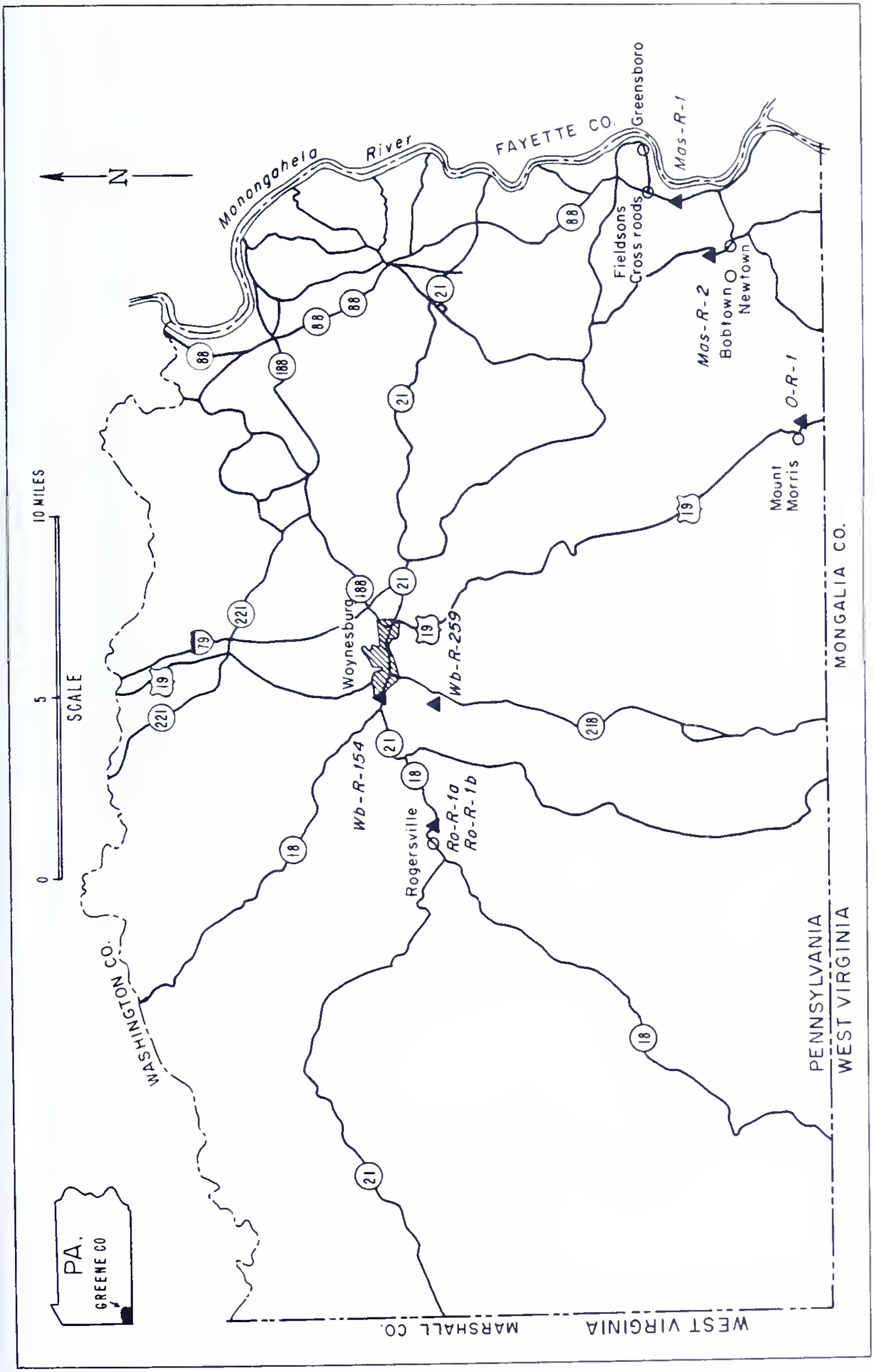

Figure 1. Index map of Greene County, Pennsylvania, showing sample localities.

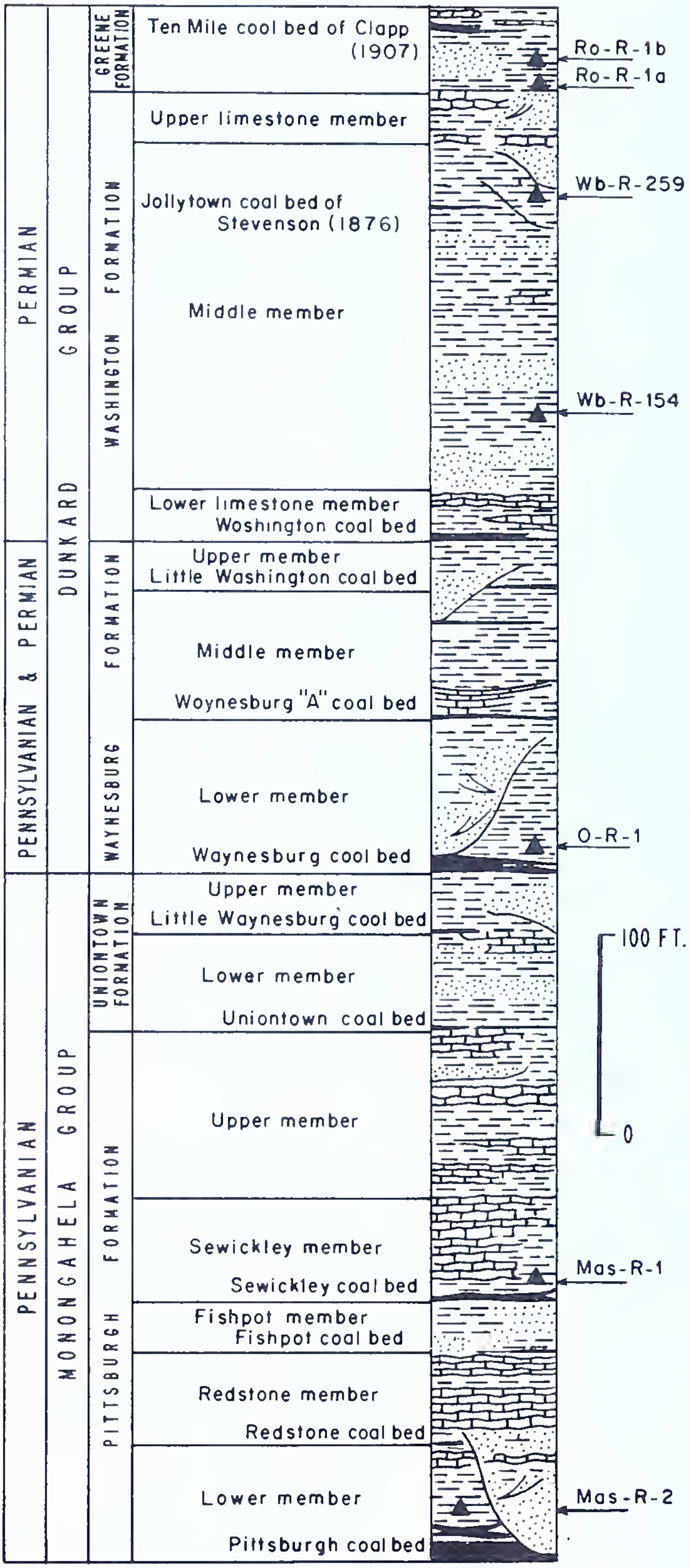

Figure 2. Generalized columnar section showing the stratigraphic position of the samples.

and Washington, are delineated top and bottom by coal beds and take their names from the beds exposed at their base. An exception to this is the Greene Formation; its base is the top of the upper limestone member of the Washington Formation. In general, geologic mapping in southwest Pennsylvania and eastern Ohio has demonstrated that coal beds have remarkable lateral continuity and are the most useful stratigraphic markers relative to the intervening monotonous clastic and limestone sequences. For the most part, therefore, the stratigraphic positions of samples collected in this study are given by reference to a coal bed.

Greene County is located in the Appalachian Plateau, a region that has a rather simple structure. The rocks are gently warped into low-amplitude anticlines and synclines trending about N. 35° E. There are a few faults, but displacements are very small and, consequently, the faults do not interrupt the continuity of the clay deposits.

SAMPLING AND ANALYTICAL METHODS

All samples collected were analyzed for mineralogical, chemical, physical, and ceramic characteristics. A 175-200-pound channel sample was collected from each of the seven localities. All samples were of fresh rock, except one (Mas-R-2), which was slightly weathered. The stratigraphic sequence at each locality was determined in order to relate the sampled beds to marker beds. Colors were described according to the Munsell color designation (Goddard, 1948). A 5-pound sample split was retained by the U. S. Geological Survey for chemical, semiquantitative spectrographic, and mineralogical analyses. The remainder was sent to the U. S. Bureau of Mines Tuscaloosa Metallurgy Research Laboratory, Tuscaloosa, Ala., for physical and ceramic analyses.

The chemical compositions of the seven samples were determined by Sarah M. Berthold of the U. S. Geological Survey.

The mineral composition was determined by X-ray diffraction methods. A small split of the sample was dried, ground to pass 170 mesh, and pressed into a 1¼-inch-diameter wafer. The clay-size fraction was removed and made into an oriented aggregate using the porous-tile method described by Kinter and Diamond (1956, p. 111-120). Both the wafer and oriented aggregate were exposed to high-intensity copper radiation using a 1.0-degree beam slit, medium resolution soller slit, a diffracted-beam monochromator, and a scintillation counter. The kind and amount of clay minerals identified for each sample are listed in the section on analytical data and test results. The proportions of different minerals were estimated using the method described by Schultz (1960,

1964) in conjunction with the chemical analyses. The average error in estimating the percentages of clay minerals is ± 10 percent of the percent indicated.

The physical and ceramic tests included Atterberg and slow-fire tests on all seven samples, quick-fire tests on four of the seven samples, and an additional rotary-kiln test on three of the four quick-fired samples. These tests were under the direction of M. E. Tyrrell, U. S. Bureau of Mines. Results of the tests are given in the section titled analytical data and test results. The procedures used by the U. S. Bureau of Mines to determine the ceramic properties of the clay and shale are outlined below.

The samples were dried at about 110°F and then ground to pass through a 20-mesh screen. One hundred grams were used for the Atterberg test (Klinefelter and Hamlin, 1957, p. 20), which is a measurement of the workability and the minimum amount of water needed for the clay to become plastic (water of plasticity). The water-moist material was molded into five uniform-size small bricks and allowed to dry slowly. The drying-shrinkage percentage, dry strength, and drying characteristics were carefully measured.

The five small bricks were then placed in a furnace and slowly heated from room temperature to 2300°F. At temperatures of 1800°, 2000°, 2100°, 2200°, and 2300°F, respectively, one brick was extracted at a time and allowed to cool slowly. The above temperatures were chosen because they bracket temperatures used in the brick-making industry. After the bricks cooled, the color, hardness, percent linear shrinkage, percent absorption, percent apparent porosity, and bulk density of each were measured. The Munsell color designations (U. S. Dept. Agriculture, 1954) and ISCC-NBS color names (Kelly and Judd, 1955) were used to describe the tested samples.

The quick-firing test is designed to determine the bloating characteristics of clays and shales within the range of temperatures used in industry. A sample consisting of ½-inch lumps was placed on a refractory slab or boat, which was placed in a preheated (1800°F) kiln for 15 minutes and then removed. The kiln temperature was raised in 100°F steps, and subsequent samples were processed in the same manner at 1900°, 2000°, 2100°, 2200°, 2300°, and 2400°F, respectively (Hamlin and Templin, 1962). Data obtained from the quick-firing tests are percent absorption, bulk density, and bloating properties.

The rotary kiln is designed to test the bloating characteristics of clay and shale under conditions used in industry. Hamlin and Templin (1962, p. 13-15) described the rotary kiln and its operation in detail. In the present study the kiln was fired to an optimum temperature indicated by the quick-firing tests to give a product weighing between

45 and 60 pounds per cubic foot. A 50-pound sample of material was fed into the hopper of the kiln. During the operation of the kiln, the temperature was slowly raised until logging or sticking occurred. The logging temperature was recorded and is referred to as the maximum bloating temperature. Practice has shown that the minimum bloating temperature, or the initial temperature at which bloating begins, is as much below the optimum temperature as the maximum temperature is above (Tyrrell, oral commun., 1968). The difference between the logging or maximum bloating temperature and the estimated minimum bloating temperature is the approximate bloating temperature range.

The ceramic tests of clay and shale by laboratory methods should be considered as preliminary and not a criteria for the design of commercial plants. To manufacture ceramic products, additional testing in a pilot plant is necessary.

CRITERIA FOR EVALUATING CLAYS AND SHALES

The criteria for evaluating the ceramic utility of clay and shale are presented in Tables 1 and 2. Table 1 lists the unfired and fired properties desirable for structural clay products, such as brick, tile, and pipe. Table 2 presents the physical characteristics needed for the production of lightweight aggregate by rotary-kiln or sintering processes. Inasmuch as the materials tested here lack the high plasticity necessary for workability, the criteria for pottery and stoneware (O'Neill and others, 1965) are not presented. Also, the shales and clays tested here do not have the chemical and mineral composition generally suitable for high-quality nonceramic products such as fillers, so no criteria for evaluation of materials for such products will be presented. For information concerning the characteristics of raw materials suitable for pottery and nonceramic uses, the reader is referred to Klinefelter and Hamlin (1957).

The physical characteristics of the unfired and fired shale and clay outlined in Tables 1 and 2 are generally controlled by the mineral composition. The exact effects that various proportions and combinations of the constituent minerals have upon the fired or unfired properties of the material are very difficult to predict and are beyond the scope of this paper. However, a few important properties of the principal minerals are mentioned below.

The clay minerals found in the samples tested here are kaolinite, illite, chlorite, and mixed-layer clay. The nonclay minerals in the samples are quartz, feldspar, and calcite. Kaolinite is a refractory mineral that can withstand high temperatures without detrimental effects. Illite is

Table 1.—Criteria used in evaluating clays and shales for structural clay products.[1]

	Common brick	*Face brick*	*Decorative brick*	*Hollow tile*	*Wall tile*	*Drain tile*	*Roofing tile*	*Floor tile*	*Flue tile*	*Architectural terra cotta*	*Sewer pipe*
UNFIRED PROPERTIES											
Workability	Low to good plasticity	Low to good plasticity	Low to good plasticity	Good to high plasticity; smooth	Good to high plasticity; smooth	Good to high plasticity; smooth	Good to high plasticity; smooth	Good to high plasticity; smooth	Good to high plasticity; smooth	High plasticity; smooth	Good to high plasticity; smooth
Water of plasticity, %	15-40	15-40	15-40	0-35	0-35	15-40	0-35	0-35	15-40	18-35	0-35
Green strength, dry	Low to high	Low to high	Low to high	Average to high	Average to high	Average to high	Average to high	Average to high	Average to high	Average to high	Average to high
Drying characteristics	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking
Drying shrinkage, %[2]	0-12	0-12	0-12	0-8	0-8	0-8	0-8	0-8	0-8	Up to 8	0-8
FIRED PROPERTIES											
Maturing temp., °F	1800-2000	1800-2200	1800-2200	1800-2100	1800-2100	1800-2000	1800-2200	1800-2200	1800-2400	2000-2200	1800-2100
Hardness, Moh's	5-6	5-7	5-7	7	7	5-6	7	7	6-7	7	7
Absorption, %	Up to 20	Up to 15	Up to 15	Up to 15	0-10	0-12	0-10	0-20	0-20	8-25	0-8
Shrinkage, %[2]	0-10	0-10	0-10	0-10	0-10	0-8	0-8	0-8	0-8	0-8	0-10
Color	Reds to browns	Reds, browns, buffs, creams	Unusual colors, pinks, grays, etc.	Not critical, usually red, brown-red, buffs	White, buffs, reds, creams	Buffs to red-browns	Buffs, reds, browns	Reds, buffs, dark browns	Buffs, reds, and red-brown	Reds, buffs, gray-buffs, off-whites	Reds, red-brown
Scumming	Slight	None	None	Slight	None	Slight	None	None	None	None	None

[1] Modified from O'Neill and others (1965).

[2] Commercially, total for shrinkage of unfired and fired product should not exceed 15 percent.

Table 2.—Criteria used in evaluating clays and shales for lightweight aggregate.[1]

	Rotary-Kiln Process	*Sintering Process*
UNFIRED PROPERTIES		
Drying characteristics	Dry readily and show only slight disintegration	Not critical, water used to pelletize before firing
Dry strength	Must be sufficient for proper sizing when crushed for kiln feed	Not critical
Crushing characteristics	-8 mesh material should not exceed 20% by weight	Not critical except when particles tend to be thin and platy
FIRED PROPERTIES		
Firing range	1800-2200°F	Vitreous and glazed, 2200-2300°F
Bloating range	Minimum 50°F[2]	Not critical
Density	75-45 lb/ft^3	75-45 lb/ft^3
Expansion	Gradual weight decrease through bloating range	Slight
Absorption, %	0-18.0 at best bloating temp.	0-6.0
Strength	Determined by concrete performance test	Determined by concrete performance test

[1] Modified from O'Neill and others (1965).
[2] M. E. Tyrrell, oral communication, 1968.

the major mineral controlling plasticity, and because of the alkalies it contains it fuses at low temperatures. The mixed-layer clay mineral is composed of random sequences of illite and montmorillonite layers. The number of illite layers probably exceed the number of montmorillonite layers by about 3:1; therefore, the mixed-layer clay mineral resembles illite in physical and ceramic properties. Chlorite also fuses at low temperatures because it contains iron and manganese. Nonclay minerals lower the plasticity if present in large amounts, but they tend to reduce drying and firing shrinkage. Quartz has no effect when fired, except as a dilutent. Feldspar and calcite flux at low temperatures because of the alkalies present.

ANALYTICAL DATA AND TEST RESULTS

Each channel sample was taken from a known stratigraphic interval at the sample locality. The locality is described so that it can be recovered with reference to the appropriate 7½-minute quadrangle map, or to Figure 1. The data and resulting evaluation based on a channel sample for an interval should not be considered representative for that clay or shale interval throughout Greene County or, for that matter, throughout the individual locality. Lateral variations are common; therefore, detailed sampling must be performed to evaluate properly each site for commercial development. Except for the semiquantitative spectrographic analyses (Table 3), the analytical data and evaluation for each sample are given separately on the following pages.

Table 3.—Semiquantitative 6-step spectrographic analyses of selected shales and clays from Greene County, Pa.

[Si, Al, Fe, Mg, Ca, Na, K, and Ti are reported in percent; all others in ppm. Results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as midpoints of these brackets, 1., 0.7, 0.5, 0.3, 0.2, 0.15, 0.1 etc. The precision of a reported value is approximately plus or minus one bracket at 68 percent, or two brackets at 95 percent confidence. N, looked for but not detected. Analyst: William B. Crandell, U.S. Geological Survey]

Sample no.	Wb-R-154	Wb-R-259	Ro-R-la	Ro-R-1b	Mas-R-1	Mas-R-2	O-R-1
Si (%)	> 10.	> 10.	> 10.	> 10.	> 10.	> 10.	> 10.
Al	7.	7.	5.	7.	7.	5.	7.
Fe	5.	5.	3.	5.	5.	3.	3.
Mg	.7	.7	.5	.7	.5	.3	.5
Ca	1.0	2.0	1.5	.5	.3	.15	.2
Na	.3	.5	.7	.3	.2	.5	.2
K	2.	2.	1.5	2.	2.	1.5	3.
Ti	.15	.15	.15	.15	.15	.15	.15
Ag (ppm)	.2	.2	.2	.2	.2	.2	.2
B	50	50	50	50	50	50	50
Ba	1,000	500	300	500	500	500	500
Be	3	3	1.5	5	3	2	3
Ce	100	100	N	100	100	N	100
Co	15	15	10	20	15	7	15
Cr	70	70	50	70	70	50	70
Cu	30	30	30	30	30	20	20
Ga	20	20	15	20	20	15	20
La	70	70	50	100	70	50	70
Mo	3	3	5	3	3	3	3
Nb	10	10	10	10	10	10	10
Nd	N	N	N	100	N	N	N
Ni	50	30	30	70	50	20	50
Pb	20	20	20	20	20	15	20
Sc	15	15	10	15	15	10	15
Sr	300	150	100	150	150	70	100
V	100	70	50	100	70	50	70
Y	20	20	20	30	20	20	20
Yb	2	2	2	3	2	2	2
Zr	100	150	150	150	100	150	150

Looked for but not detected: As, Au, Bi, Cd, Eu, Ge, Hf, In, Li, P, Pd, Pr, Pt, Re, Sb, Sm, Sn, Ta, Te, Th, Tl, U, W, Zn.

Sample Wb-R-154

QUADRANGLE: Waynesburg 15′; Waynesburg 7½′

LOCATION: West of Waynesburg at intersection of Pennsylvania Route 21 and Toll Gate Run road. Sample collected from high bank on northwest corner of intersection.

GEOLOGIC SECTION:

Washington Formation (Permian):
Middle member:

	Thickness (feet)
5. Shale, weathered; top not exposed	5.0+
4. Sandstone, very fine grained; beds 1-6 inches thick, cross bedded; few shale interbeds	9.2
3. Siltstone and interbedded silty shales; contains a very few ironstone nodules	11.7
2. Shale, medium-gray to medium-dark-gray; contains ironstone nodules; lower beds poorly exposed	17.4
1. Sandstone very fine grained; thin-, even-bedded. Top of this sandstone near level of Pennsylvania Route 21 and is exposed on the south side of Route 21. Top of this unit is approximately 50 feet above the base of the Washington Formation	2.4

SAMPLE INTERVAL: 10-foot channel sample from lower part of unit 2

ATTITUDE OF BEDDING: Virtually horizontal

CHEMICAL ANALYSIS:

	%
SiO_2	52.22
Al_2O_3	19.99
Fe_2O_3	2.83
FeO	4.75
MgO	1.96
CaO	1.88
Na_2O	.58
K_2O	3.6
H_2O+	5.56
H_2O-	2.20
TiO_2	.94
P_2O_5	.85
MnO	.11
CO_2	2.32
Cl	.08
F	.10
S	.20
C (organic)	.37
Total	100.54
Less O = Cl	.02
O = F	.04
O = S	.10
Sum	100.38

MINERALOGY: X-ray analysis:

	%
Kaolinite	25
Illite	30
Mixed-layer clay	15
Chlorite	5
Quartz	20
Feldspar	—
Calcite	5
Sum	100

UNFIRED PROPERTIES:

Color of composite dry sample (Munsell designations): Medium gray (N 6)
Water of plasticity: 14.6 percent
Workability: Low plasticity
Green strength, dry: Low
Drying characteristics: No defects
Drying shrinkage: 0.0 percent
pH: 8.0
Remarks: Slight effervescence in HCl

FIRING TESTS AND PROPERTIES:

Slow-firing test:

Temp., °F	*Color, Munsell designation*	*Moh's Hardness*	*Total shrinkage, percent*	*Absorption, percent*	*Apparent porosity, percent*	*Bulk density, gm/cc*
1800	Dusky yellowish orange (7.5 YR 6/6)	3	2.5	8.8	18.1	2.06
1900	Same as above	4	5.0	7.5	15.8	2.11
2000	Moderate yellowish brown (7.5 YR 5/6)	6	5.0	4.6	10.2	2.21
2100	Weak brown (7.5 YR 4/2)	7	7.5	.3	.7	2.34
2200			Expanded			

Remarks: Positive bloating characteristics indicate further testing required for evaluation.

Quick-firing test (preliminary bloating):

Particle size: Extruded rods 1 inch in diameter by 1 inch long
Retention time: 15 minutes for each temperature setting

Temp., °F	*Absorption, percent*	*Bulk density gm/cc*	*Bulk density lb/ft³*	*Remarks*
1900	7.2	1.87	116.7	No expansion
2000	6.9	1.46	91.1	Slight expansion
2100	8.1	1.18	73.6	Good pore structure
2200	10.1	.88	54.9	Some large pores

Remarks: Possible raw material for lightweight aggregate. Pore structure shown in Plate 1, Figures A, B and C.

Rotary-kiln test:

Raw material:
Fragment shape: Extruded rods 1 inch in diameter by 1 inch long
Crushing loss (–4 mesh): None

Firing data:
Pour weight of feed: 80 lb/ft³
Optimum bloating temperature: 2275°F
Logging temperature: 2290°F (Nodules sticking together)
Approximate bloating range: 30°F
Fired material: (All fired material crushed through roll crusher)

Screen analysis of coarse-size fraction:

U. S. standard sieve size	*Weight passing sieve, percent*
¾ inch	100
½ inch	71.9
⅜ inch	53.4
No. 4	32.2
No. 8	26.1

Coarse loose pour weight: 44 lb/ft³

EVALUATION: Potential raw material for the manufacture of bricks used in areas subjected to extreme frost action. Preliminary firing tests suggested the material was suitable for the production of lightweight aggregate, but the rotary-kiln test indicates the material is marginal owing to the short bloating range temperature of 30°F.

Sample Wb-R-259

QUADRANGLE: Waynesburg 15′; Waynesburg 7½′

LOCATION: Greene County Clay Products Quarry located 1.5 miles south of Waynesburg and 0.5 mile west of Pennsylvania Route 218. Sample taken from highwall on the north side of the hollow.

GEOLOGIC SECTION:

Washington Formation (Permian): *Middle member:*	*Thickness (feet)*
13. Sandstone, fine- to medium-grained, massive, thick-bedded	20.0
12. Clay, reddish-gray and greenish-gray; numerous compaction slip planes	11.2
11. Clay, greenish-gray, nonbedded	1.0
10. Siltstone, poorly bedded	0.6
9. Clay, greenish-gray, nonbedded	1.6
8. Shale, silty	1.0
7. Clay, greenish-gray, poorly bedded	4.2
6. Siltstone and very fine-grained sandstone, gray; irregularly bedded to nonbedded; grades laterally to silty shale	5.0±
5. Clay, greenish-gray, poorly bedded; variable thickness	1.3±
4. Clay, greenish-gray, nonbedded	3.0
3. Covered	2.5
2. Sandstone, very fine grained, limy, nodular	1.0±
1. Sandstone, fine-grained, light-gray; contains 70%± quartz; calcareous; thin-, even-bedded; base not exposed	10.5

SAMPLE INTERVAL: 28.9-foot channel sample from units 4-12
ATTITUDE OF BEDDING: Virtually horizontal

CHEMICAL ANALYSIS:

	%
SiO_2	53.62
Al_2O_3	16.76
Fe_2O_3	3.50
FeO	4.05
MgO	2.12
CaO	3.74
Na_2O	.55
K_2O	3.20
H_2O+	4.93
H_2O-	1.77
TiO_2	1.06
P_2O_5	.51
MnO	.10
CO_2	3.48
Cl	.06
F	.08
S	.20
C (organic)	.12
Total	99.85
Less O = Cl	.01
O = F	.03
O = S	.10
Sum	99.71

MINERALOGY: X-ray analysis:

	%
Kaolinite	15
Illite	30
Mixed-layer clay	25
Chlorite	tr
Quartz	25
Feldspar	—
Calcite	5
Sum	100

UNFIRED PROPERTIES:

Color of composite dry sample (Munsell designations): Light brownish gray (10 YR 5/1)
Water of plasticity: 14.6 percent
Workability: Low plasticity
Green strength, dry: Low
Drying characteristics: No defects
Drying shrinkage: 0.0 percent
pH: 8.2
Remarks: Calcareous, high effervescence in HCl

FIRING TESTS AND PROPERTIES:

Slow-firing test:

Temp., °F	*Color, Munsell designation*	*Moh's Hardness*	*Total shrinkage, percent*	*Absorption, percent*	*Apparent porosity, percent*	*Bulk density, gm/cc*
1800	Weak orange (5 YR 6/6)	2	2.5	11.6	22.3	1.92
1900	Same as above	3	5.0	10.8	21.3	1.98
2000	Light brown (5 YR 5/6)	6	5.0	7.6	15.9	2.09
2100	Moderate brown (5 YR 3/3)	7	7.5	.6	1.4	2.27
2200			Expanded			

Remarks: Negative bloating characteristics indicate no further testing desirable.

EVALUATION: Material may be used for the manufacture of common, face, and decorative brick.

Sample Ro-R-1a

QUADRANGLE: Rogersville 15′; Rogersville 7½′

LOCATION: Waynesburg Southern Railroad cut 0.5 mile east of Rogersville and due south of Rosemont Cemetery on the south side of the south fork of Ten Mile Creek; approximately 500 feet south of Pennsylvania Route 21.

GEOLOGIC SECTION:	*Thickness (feet)*
Greene Formation (Permian):	
10. Coal and carbonaceous shale, Ten Mile coal bed of Clapp (1907)	1.5
9. Clay, medium-gray to medium-dark-gray, poorly bedded to bedded; silty in upper 12 feet; lower 8 feet fresh; upper 12.5 feet weathered	20.5
8. Clay, grayish-black, carbonaceous, shaly, fresh; contains ostracodes	2.8
7. Clay, light-gray, silty, very poorly bedded; contains a few limy nodules	4.7
6. Clay, medium-dark-gray, poorly bedded	0.8±
Washington Formation (Permian):	
Upper limestone member:	
5. Limestone, light-gray, weathers yellowish-orange, argillaceous	0.5
4. Clay, medium-dark-gray	1.0±
3. Limestone, light-olive-gray, weathers to very light gray to white, very finely crystalline	3.0
2. Clay, light-gray, calcareous	0.5
1. Limestone, light-gray to light-olive-gray	0.6±

SAMPLE INTERVAL: 2.8-foot channel sample from unit 8

ATTITUDE OF BEDDING: Virtually horizontal

CHEMICAL ANALYSIS:

	%
SiO_2	58.84
Al_2O_3	12.08
Fe_2O_3	4.72
FeO	3.25
MgO	1.40
CaO	2.66
Na_2O	1.1
K_2O	2.3
H_2O^+	3.63
H_2O^-	1.78
TiO_2	.94
P_2O_5	.77
MnO	.14
CO_2	1.15
Cl	.21
F	.11
S	.84
C (organic)	4.92
Total	100.84
Less O = Cl	.05
O = F	.05
O = S	.42
Sum	100.32

MINERALOGY: X-ray analysis:

	%
Kaolinite	20
Illite	20
Mixed-layer clay	5
Chlorite	5
Quartz	35
Feldspar	10
Calcite	5
Sum	100

UNFIRED PROPERTIES:

Color of composite dry sample (Munsell designations): Dark gray (N3)
Water of plasticity: 17.4 percent
Workability: Low plasticity
Green strength, dry: Low
Drying characteristics: No defects
Drying shrinkage: 0.0 percent
pH: 6.3

FIRING TESTS AND PROPERTIES:

Slow-firing test:

Temp., °F	*Color, Munsell designation*	*Moh's Hardness*	*Total shrinkage, percent*	*Absorption, percent*	*Apparent porosity, percent*	*Bulk density, gm/cc*
1800	Light brown (5 YR 6/6)	2	0.0	21.6	36.0	1.62
1900	Same as above	2	2.5	19.3	32.8	1.70
2000	Same as above	3	5.0	16.0	28.6	1.79
2100	Moderate brown (5 YR 3/3)	7	10.0	7.6	14.7	1.94
2200			Expanded			

Remarks: Negative bloating characteristics indicate no further testing desirable.

EVALUATION: Potential material for common, face, and decorative brick but may be limited by shrinkage.

Sample Ro-R-1b

QUADRANGLE: Rogersville 15′; Rogersville 7½′

LOCATION: Waynesburg Southern Railroad cut 0.5 mile east of Rogersville and due south of Rosemont Cemetery on the south side of the south fork of Ten Mile Creek; approximately 500 feet south of Pennsylvania Route 21.

GEOLOGIC SECTION:

		Thickness (feet)
Greene Formation (Permian):		
10.	Coal and carbonaceous shale, Ten Mile coal bed of Clapp (1907)	1.5
9.	Clay, medium-gray to medium-dark-gray, poorly bedded to bedded; silty in upper 12 feet; lower 8 feet fresh; upper 12.5 feet weathered	20.5
8.	Clay, grayish-black, carbonaceous, shaly, fresh; contains ostracodes	2.8
7.	Clay, light-gray, silty, very poorly bedded; contains a few limy nodules	4.7
6.	Clay, medium-dark-gray, poorly bedded	0.8±
Washington Formation (Permian):		
Upper limestone member:		
5.	Limestone, light-gray, weathers yellowish-orange, argillaceous	0.5
4.	Clay, medium-dark-gray	1.0±
3.	Limestone, light-olive-gray, weathers to very light gray to white, very finely crystalline	3.0
2.	Clay, light-gray, calcareous	0.5
1.	Limestone, light-gray to light-olive-gray	0.6±

SAMPLE INTERVAL: 20.5-foot channel sample from unit 9

ATTITUDE OF BEDDING: Virtually horizontal

CHEMICAL ANALYSIS:	%
SiO_2	53.00
Al_2O_3	20.74
Fe_2O_3	4.27
FeO	2.30
MgO	1.82
CaO	.66
Na_2O	.51
K_2O	3.4
H_2O^+	7.15
H_2O^-	2.81
TiO_2	1.06
P_2O_5	.57
MnO	.11
CO_2	.32
Cl	.15
F	.10
S	.04
C (organic)	.73
Total	99.74
Less O = Cl	.03
O = F	.04
O = S	.02
Sum	99.65

MINERALOGY: X-ray analysis:	%
Kaolinite	30
Illite	30
Mixed-layer clay	15
Chlorite	5
Quartz	20
Feldspar	—
Calcite	—
Sum	100

UNFIRED PROPERTIES:

Color of composite dry sample (Munsell designations): Light brownish gray (5 YR 5/1)

Water of plasticity: 16.6 percent

Workability: Low plasticity

Green strength, dry: Low

Drying characteristics: No defects

Drying shrinkage: 2.5 percent

pH: 7.1

FIRING TESTS AND PROPERTIES:

Slow-firing test:

Temp., °F	*Color, Munsell designation*	*Moh's Hardness*	*Total shrinkage, percent*	*Absorption, percent*	*Apparent porosity, percent*	*Bulk density, gm/cc*
1800	Weak orange (5 YR 7/6)	3	2.5	11.4	22.3	1.96
1900	Same as above	4	5.0	7.6	15.8	2.08
2000	Light brown (5 YR 5/6)	6	7.5	4.5	10.0	2.23
2100	Weak reddish brown (2.5 YR 4/4)	7	12.5	4.5	9.7	2.15
2200			Expanded			

Remarks: Positive bloating characteristics indicate further testing required for evaluation.

Quick-firing test (preliminary bloating):

Particle size: Extruded rods 1 inch in diameter by 1 inch long

Retention time: 15 minutes for each temperature setting

Temp., °F	*Absorption, percent*	*Bulk density gm/cc*	*lb/ft³*	*Remarks*
1900	9.0	1.63	101.7	Slight expansion
2000	13.0	1.25	78.0	Good pore structure
2100	15.3	.88	54.9	Good pore structure
2200	18.3	.62	38.7	Same large pores

Remarks: Possible raw material for lightweight aggregate. Pore structure shown in Plate 1, Figures D, E, and F.

Rotary-kiln test:

Raw material:

Fragment shape: Extruded rods 1 inch in diameter by 1 inch long

Crushing loss (—4 mesh): None

Firing data:

Pour weight of feed: 71 lb/ft^3

Optimum bloating temperature: 2275°F

Logging temperature: 2300°F (Nodules sticking together)

Approximate bloating range: 50°F

Fired material: (All fired material crushed through roll crusher)

Screen analysis of coarse-size fraction:

U. S. standard sieve size	*Weight passing sieve, percent*
¾ inch	100
½ inch	77.2
⅜ inch	58.3
No. 4	35.7
No. 8	28.2

Coarse loose pour weight: 40.0 lb/ft^3

EVALUATION: Marginal raw material for production of brick because of firing shrinkage. The expansion characteristics and loose pour weight indicate this material may be usable for production of lightweight aggregate in a kiln that can control the bloating temperature range within 50°F.

Sample Mas-R-1

QUADRANGLE: Masontown 15′, Masontown 7½′

LOCATION: Abandoned strip mine on Sewickley coal bed; 0.67 mile south of Fieldsons Crossroads and 0.05 mile east of Pennsylvania Route 88.

GEOLOGIC SECTION:

	Thickness (feet)
Pittsburgh Formation (Pennsylvanian):	
Sewickley Member:	
5. Sandstone, very fine to fine-grained; thin even-bedded	1.0+
4. Shale, olive-gray to medium-dark-gray; silty near top; very thin-bedded	8.5
3. Shale, dark-gray to grayish-black, fissile, bony or carbonaceous	1.5
2. Shale, medium-gray to dark-gray, fissile	5.0
1. Coal, Sewickley coal bed; only top exposed, no thickness	—

SAMPLE INTERVAL: 15-foot channel sample from units 2-4

ATTITUDE OF BEDDING: Virtually horizontal

CHEMICAL ANALYSIS:

	%
SiO_2	52.65
Al_2O_3	19.12
Fe_2O_3	4.70
FeO	5.05
MgO	1.50
CaO	.55
Na_2O	.30
K_2O	3.1
H_2O^+	5.72
H_2O^-	1.30
TiO_2	1.06
P_2O_5	.24
MnO	.10
CO_2	1.48
Cl	.11
F	.08
S	.44
C (organic)	2.55
Total	100.05
Less O = Cl	.02
O = F	.03
O = S	.22
Sum	99.78

MINERALOGY: X-ray analysis:

	%
Kaolinite	30
Illite	25
Mixed-layer clay	15
Chlorite	10
Quartz	20
Feldspar	—
Calcite	—
Sum	100

UNFIRED PROPERTIES:

Color of composite dry sample (Munsell designations): Olive gray (5 Y 4/1)
Water of plasticity: 14.4 percent
Workability: Low plasticity
Green strength, dry: Low
Drying characteristics: No defects
Drying shrinkage: 0.0 percent
pH: 5.9

FIRING TESTS AND PROPERTIES:

Slow-firing test:

Temp., °F	*Color, Munsell designation*	*Moh's Hardness*	*Total shrinkage, percent*	*Absorption, percent*	*Apparent porosity, percent*	*Bulk density, gm/cc*
1800	Light brown (5 YR 6/4)	2	0.0	19.2	33.4	1.74
1900	Same as above	2	0.0	17.4	31.3	1.80
2000	Light brown (5 YR 5/4)	4	2.5	13.4	26.0	1.94
2100	Moderate brown (5 YR 3/3)	6	5.0	7.7	16.3	2.12
2200			Expanded			

Remarks: Positive bloating characteristics indicate further testing required for evaluation.

Quick-firing test (preliminary bloating):

Crushing characteristics: Tabular
Particle size: ½-inch lumps
Retention time: 15 minutes for each temperature setting

Temp., °F	*Absorption, percent*	*Bulk density gm/cc*	*Bulk density lb/ft³*	*Remarks*
1900	8.1	1.43	89.2	Slight expansion
2000	13.9	1.00	62.4	Good expansion
2100	22.5	.67	41.8	Overfired; vitreous
2200	19.3	.61	38.1	Overfired; vitreous

Remarks: Possible raw material for lightweight aggregate.

Rotary-kiln test:

Raw material:
Fragment shape: Extruded rods 1 inch in diameter by 1 inch long
Crushing loss (−4 mesh): None

Firing data:
Pour weight of feed: 68 lb/ft³
Optimum bloating temperature: 2035°F
Logging temperature: 2075°F (Nodules sticking together)
Approximate bloating range: 80°F

Fired material: (All fired material crushed through roll crusher)
Screen analysis of coarse-size fraction:

U.S. standard sieve size	*Weight passing sieve, percent*
¾ inch	100
½ inch	82.4
⅜ inch	64.1
No. 4	41.1
No. 8	33.0

Coarse loose pour weight: 44.0 lb/ft³

EVALUATION: Possible raw material for common, face, or decorative brick. Marginal material for lightweight aggregate, as it contains nonbloating materials.

Sample Mas-R-2

QUADRANGLE: Masontown 15′; Masontown 7½′

LOCATION: Approximately 0.6 mile north of Newton and about 0.75 mile northeast of Bobtown, on the north side of Dunkard Creek, just east of the bridge crossing Dunkard Creek. Sample taken from high bank on north side of highway just west of abandoned air tunnel.

GEOLOGIC SECTION:

	Thickness (feet)
Pittsburgh Formation (Pennsylvanian):	
Lower member:	
4. Carbonaceous shale, medium-dark-gray to grayish-black, silty, slightly weathered	15.0+
3. Siltstone, carbonaceous, dark-gray	6.5
2. Clay	0.5±
1. Bone coal, uppermost unit of Pittsburgh coal zone; base of Pittsburgh coal bed not exposed	2.0+

SAMPLE INTERVAL: 15-foot channel sample from unit 4

ATTITUDE OF BEDDING: Virtually horizontal

CHEMICAL ANALYSIS:

	%
SiO_2	53.45
Al_2O_3	14.69
Fe_2O_3	7.11
FeO	2.60
MgO	.88
CaO	.26
Na_2O	.42
K_2O	2.6
H_2O^+	5.60
H_2O^-	1.72
TiO_2	.94
P_2O_5	.22
MnO	.13
CO_2	.16
Cl	.06
F	.06
S	.78
C (organic)	8.48
Total	100.16
Less O = Cl	.01
O = F	.02
O = S	.39
Sum	99.74

MINERALOGY: X-ray analysis:

	%
Kaolinite	35
Illite	25
Mixed-layer clay	10
Chlorite	10
Quartz	20
Feldspar	—
Calcite	—
Sum	100

UNFIRED PROPERTIES:

Color of composite dry sample (Munsell designations): Brownish black (10 YR 2/1)
Water of plasticity: 17.5 percent
Workability: Low plasticity
Green strength, dry: Low
Drying characteristics: No defects
Drying shrinkage: 0.0 percent
pH: 3.7

FIRING TESTS AND PROPERTIES:

Slow-firing test:

Temp., °F	*Color, Munsell designation*	*Moh's Hardness*	*Total shrinkage, percent*	*Absorption, percent*	*Apparent porosity, percent*	*Bulk density, gm/cc*
1800	Weak orange (2.5 YR 6/6)	2	0.0	30.8	43.1	1.40
1900	Same as above	2	0.0	31.2	51.5	1.65
2000	Weak reddish brown (2.5 YR 4/4)	3	2.5	26.5	39.8	1.50
2100	Dusky red (2.5 YR 3/2)	4	5.0	21.2	34.6	1.63
2200	Dusky reddish brown (2.5 YR 2/4)	6	10.0	14.1	25.5	1.81
2300			Expanded			

Remarks: Negative bloating characteristics indicate no further testing desirable.

EVALUATION: Material may be used for production of common, face, or decorative brick but may be limited by high absorption.

Sample O-R-1

QUADRANGLE: Blacksville 15′; Osage 7½′

LOCATION: Strip mine on Waynesburg coal bed at end of secondary road which intersects U. S. Route 19, 0.4 mile southeast of the center of Mt. Morris. Sample taken from highwall on north side of strip pit.

GEOLOGIC SECTION:

	Thickness (feet)
4. Terrace deposits: unconsolidated silt, very fine sand and clay	0-10
Waynesburg Formation (Pennsylvanian and Permian):	
Lower member:	
3. Sandstone, very light gray, medium- to coarse-grained, thin- to thick-bedded	0-8
2. Shale, medium-gray to medium-dark-gray, silty; contains less carbonaceous material and ironstones than unit below	7.6
1. Shale, medium-dark-gray to dark-gray, slightly silty; contains ironstone bands and nodules; carbonaceous, contains coalified plant fragments and plant material and impressions	8.0
Top of Waynesburg coal bed not exposed	

SAMPLE INTERVAL: 15.6-foot channel sample from units 1 and 2

ATTITUDE OF BEDDING: Virtually horizontal

CHEMICAL ANALYSIS:

	%
SiO_2	54.85
Al_2O_3	18.17
Fe_2O_3	3.33
FeO	6.00
MgO	1.51
CaO	.40
Na_2O	.20
K_2O	3.4
H_2O^+	5.38
H_2O^-	.98
TiO_2	.94
P_2O_5	.20
MnO	.15
CO_2	2.04
Cl	.03
F	.08
S	.56
C (organic)	1.88
Total	100.10
Less O = Cl	.01
O = F	.03
O = S	.28
Sum	99.78

MINERALOGY: X-ray analysis:

	%
Kaolinite	40
Illite	30
Mixed-layer clay	tr
Chlorite	10
Quartz	20
Feldspar	—
Calcite	—
Sum	100

UNFIRED PROPERTIES:

Color of composite dry sample (Munsell designations): Medium gray (N 5)
Water of plasticity: 15.9 percent
Workability: Low plasticity
Green strength, dry: Low
Drying characteristics: No defects
Drying shrinkage: 0.0 percent
pH: 5.4

FIRING TESTS AND PROPERTIES:

Slow-firing test:

Temp., °F	*Color, Munsell designation*	*Moh's Hardness*	*Total shrinkage, percent*	*Absorption, percent*	*Apparent porosity, percent*	*Bulk density, gm/cc*
1800	Very pale brown (7.5 YR 7/2)	2	0.0	17.3	30.4	1.76
1900	Pale brown (7.5 YR 6/2)	2	0.0	16.4	29.7	1.81
2000	Pale brown (5 YR 5/3)	4	2.5	12.9	24.6	1.91
2100	Weak brown (5 YR 4/2)	6	5.0	7.2	15.3	2.13
2200			Expanded			

Remarks: Positive bloating characteristics indicate further testing required for evaluation.

Quick-firing test (preliminary bloating):

Crushing characteristics: Tabular

Particle size: ½-inch lumps

Retention time: 15 minutes for each temperature setting

Temp., °F	*Absorption, percent*	*Bulk density gm/cc*	*lb/ft³*	*Remarks*
1900	6.7	1.72	107.3	Slight expansion
2000	15.7	1.23	76.8	Some lumps overbloated
2100	14.3	1.00	62.4	Some lumps overbloated
2200	19.3	.80	49.9	Some lumps melting

Remarks: Not suitable raw material for lightweight aggregate. Mixture of bloating and nonbloating material.

EVALUATION: Potential use as a raw material for common, face, and decorative brick. Preliminary bloating tests indicate the material is not suitable for lightweight aggregate.

SUMMARY OF RESULTS

The results of the slow-fire tests conducted by the U. S. Bureau of Mines Tuscaloosa Metallurgy Research Laboratory indicate that six of the seven samples tested represent clay and shale suitable for the manufacture of brick. Of these six samples, Wb-R-154 represents material that should fire to the highest quality brick. This type of brick, referred to as the SW grade (Klinefelter and Hamlin, 1957), has low absorption and will not disintegrate under freezing and thawing conditions. Except for sample Ro-R-1b, which is a marginal raw material because of relatively high firing shrinkage, the remaining samples are representative of material suitable for the production of common, face, and decorative brick. They all meet the specifications set forth in Table 1 for the manufacture of the various brick types. All have a low green strength and a low degree of workability. These two characteristics are permissible in brick making (Table 1); however, they preclude the use of these materials in the production of tile, pipe, pottery, and earthenware.

Both the slow-fire and the quick-fire tests serve as a basis for selecting samples for the rotary-kiln test. Positive bloating characteristics from the slow-fire tests for samples Wb-R-154, Mas-R-1, Ro-R-1b, and O-R-1 indicated that these samples should be further tested by quick firing to determine their potential as raw material for lightweight aggregate. In the quick-fire tests, samples Wb-R-154, Mas-R-1, and Ro-R-1b expanded sufficiently with enough pore structure to be considered potential raw material for lightweight aggregate and were tested in the rotary kiln. Plate 1 shows the development and distribution of the pore structures of samples Wb-R-154 and Ro-R-1b at temperatures of 2000°, 2100°, and 2200°F. In comparison, note that sample Wb-R-154 is more porous and has a more uniform pore structure. Sample O-R-1, a carbonaceous shale, when quick fired was judged not suitable for the rotary-kiln because it contained an appreciable amount of nonbloating material.

In the rotary-kiln test of sample Wb-R-154, the temperature was raised slowly from the optimum of 2275°F until logging or sticking occurred at the maximum temperature of 2290°F. The approximate bloating temperature range of the sample is equal to twice the difference between the optimum and maximum temperature, or about 30°F. The fired material has a loose pour weight of 41.0 pounds per cubic foot and is within the range (45-75 lb/ft^3) set forth in Table 2; however, the narrow bloating range limits the utility of the material, as it would necessitate rigid kiln-temperature control, which is impractical for commercial production.

Sample Mas-R-1 was tested in the rotary kiln at an optimum temperature of 2035°F. The logging temperature was 2075°F, producing an approximate bloating temperature range of 80°F. The loose pour weight of the fired product was 44 pounds per cubic foot. Despite the favorable bloating range, the fired material contained enough nonbloating nodules to render it marginal for the manufacture of lightweight aggregate.

Temperature data from firing sample Ro-R-1b in the rotary kiln indicate an approximate expansion range of 50°F. The material was initially fired at the optimum temperature of 2275°F and the sticking began at 2300°F. The kiln produced a coarse aggregate having a loose pour weight of 40.0 pounds per cubic foot. The favorable pore structure and expansion characteristics indicate that this material may be fired into a usable lightweight aggregate in a modern kiln of sufficient temperature control to accommodate the narrow bloating temperature range of 50°F.

Materials failing to meet or having marginal rotary kiln specifications should not be considered as unusable for lightweight aggregate production. A second method, the sintering process (Table 2) can be used when the raw material does not bloat or has sticking tendencies resulting from a narrow bloating range. Sintered aggregate is produced by processing a mixture of ground clay and/or shale and coal or coke on a grate that moves through a furnace. Under the intense heat of the furnace flame, the particles coalesce and the carbon is burned off. The product is a lightweight vesicular mass that is crushed and sized after it leaves the furnace. Sintering plants are in operation but are fewer in number than rotary-kiln operations. Although the specifications for the raw material are much less exacting than for the rotary kiln, the processing costs for sintering are higher.

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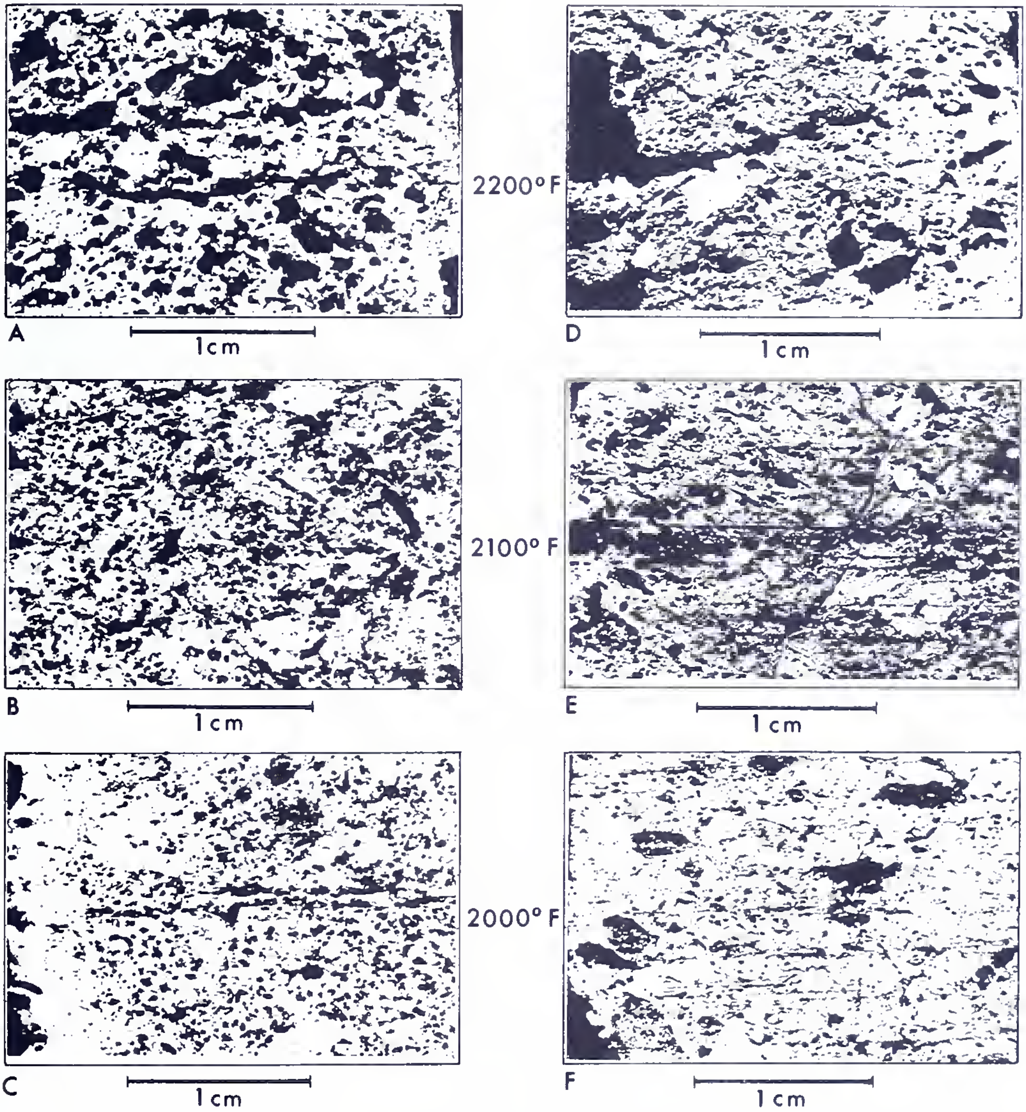

Plate 1.—Sawed surfaces of sample Wb-R-154 and Ro-R-1b showing the pore structure after quick firing at 2000°, 2100°, and 2200°F.